

High multiplicity processes with BlackHat and Sherpa



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In collaboration with

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Outline

- BlackHat+Sherpa n-Tuple files and library
- Universal behaviour in W+jets production

BlackHat+Sherpa

- BlackHat is a C++ library for virtual one-loop matrix elements
- Recent calculations with Sherpa:
 - W/Z+4 jets
 - 2,3,4 jets
 - Z/gamma ratios with up to 3 jets
 - W+5 jets
 - diphoton+2 jets

n-Tuple files [arXiv:1310.7439]

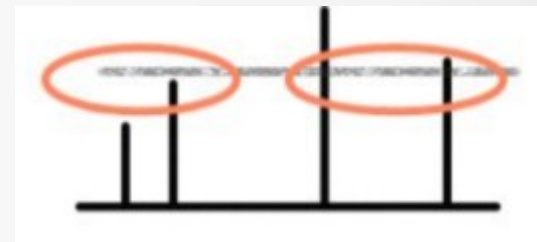
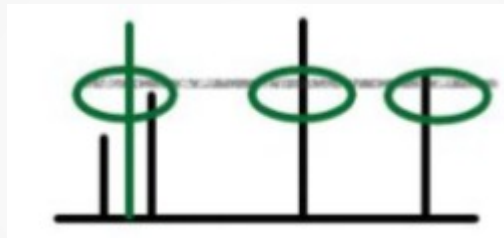
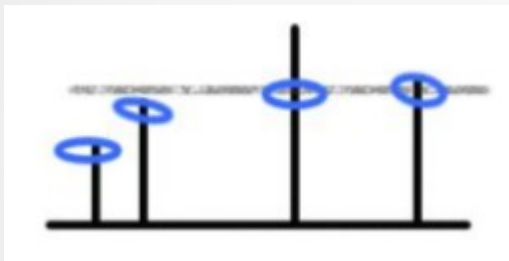
- High multiplicity NLO calculations are computationally intensive
- It would not be possible to rerun a high multiplicity W+jet calculation every time a new interesting observable comes up
- Matrix elements are expensive, while
 - Jet clustering
 - Observables
 - PDF evaluationare relatively cheap
- Store each matrix element, PS point and the information necessary to change the factorisation and renormalisation scales in large files we call n-Tuple files
- We use ROOT file as storage

n-Tuple files

- Goodies
 - One can change the analysis cuts, add observables
 - Scale variation
 - PDF errors (otherwise extremely expensive)
 - Easy communication between theorists and experimenters
 - No need for specific know-how of the tool which produced them
- Price to pay
 - Large files
 - Generation cuts need to be loose enough to accommodate many analysis --> efficiency cost

n-Tuple files

- At NLO for a fixed jet p_t threshold the n -jet samples are not 'inclusive' in the sense that having n jets for a given cone radius does not guarantee that one has at least n jets for a smaller cone radius



- As a consequence a NLO sample cannot work for any jet parameters
- Several jet algorithms are supported:
 - Anti-kt, kt, Siscone (merging fraction 0.75)
 - $R=0.4, 0.5, 0.6, 0.7$

n-Tuple availability

- The n-Tuple files are available
 - On the grid
 - On castor at CERN
- For a range of processes

Process	Pathname	Energy	Jet cut
W+ + 1,2,3,4 jets	Wp<n>j	7TeV	25GeV
W+ + 1,2,3 jets	Wp<n>j	8TeV	20GeV
W- + 1,2,3,4 jets	Wm<n>j	7TeV	25GeV
W- + 1,2,3 jets	Wm<n>j	8TeV	20GeV
Z/gamma* + 1,2 jets	Zee<n>j	7TeV	25GeV
Z/gamma* + 3,4 jets	Zee<n>j	7TeV	20GeV
Z/gamma* + 1,2,3 jets	Zee<n>j	8TeV	20GeV
2,3,4 jets	PureQCD<n>j	7TeV,8TeV	40GeV

From <http://blackhat.hepforge.org/trac/wiki/Availability>

nTupleReader library

- We provide a C++ library to facilitate the use of the n-Tuple files
- Allows:
 - Change of factorisation and renormalisation scales
 - Change of pdf (from LHAPDF set), including error sets
- Has a Python interface
- Template for a customised implementation
- Available on [hepforge](#)

nTupleReader library

- Example

```
import nTupleReader as NR
r=NR.nTupleReader()
r.addFile('sample.root')

r.setPDF("CT10nlo.LHgrid")
r.setPDFmember(12)

while r.nextEntry():
    # compute new scales
    RenScale = ....
    FacScale = ....
    newWeight=r.computeWeight(FacScale,RenScale)
    // use this weight in the analysis
    ...
```

Pitfalls

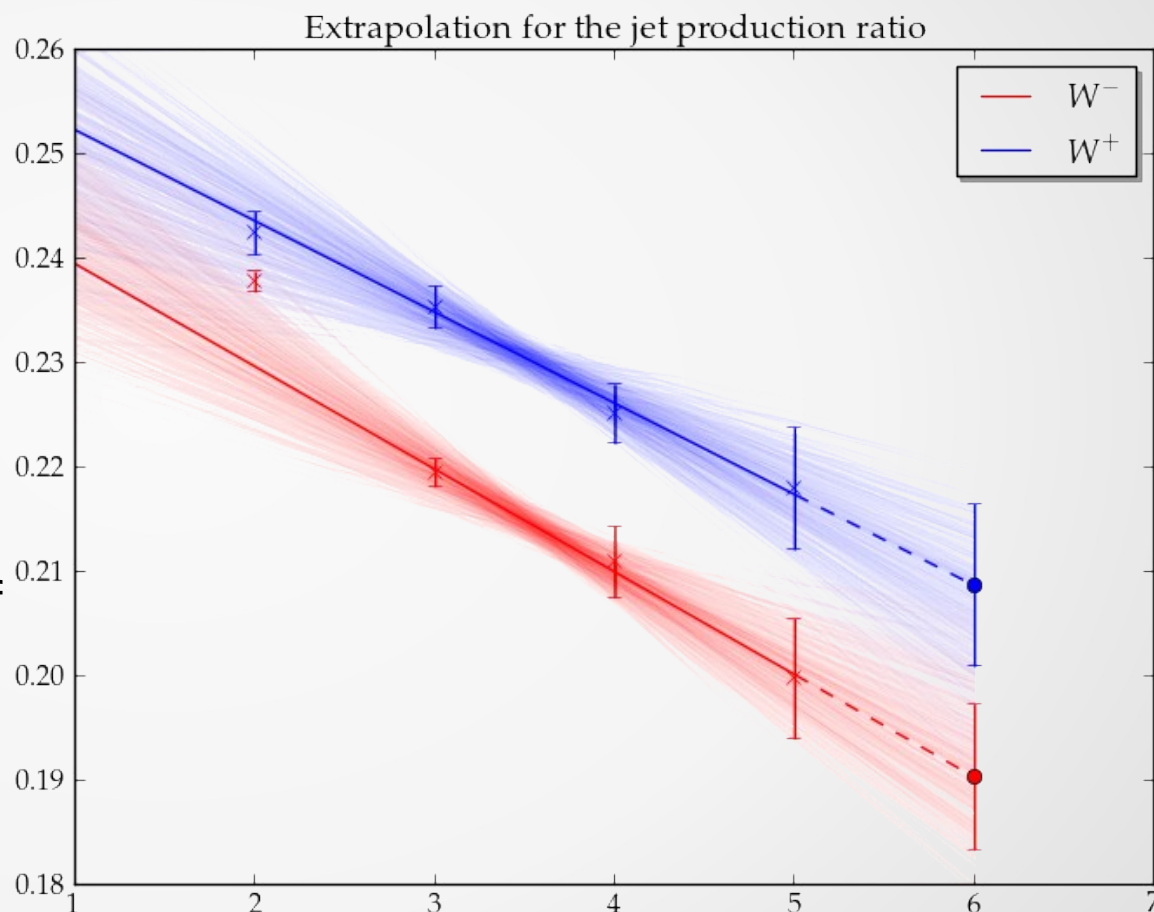
- There can be negative weights
- For the real part the matrix elements and the subtraction terms are highly anti-correlated (by construction)
- Some common operations have to be modified to take this into account:
 - statistical error calculation
 - Rebinning, cumulative distributions

Towards higher multiplicities?

- We have a lot of prediction for high multiplicity processes at NLO
- We can try to find 'universal' properties/features
- Usually need to discard 0-jet and 1-jet because new partonic channels open
- Usually these features are more easily seen in ratios between multiplicities

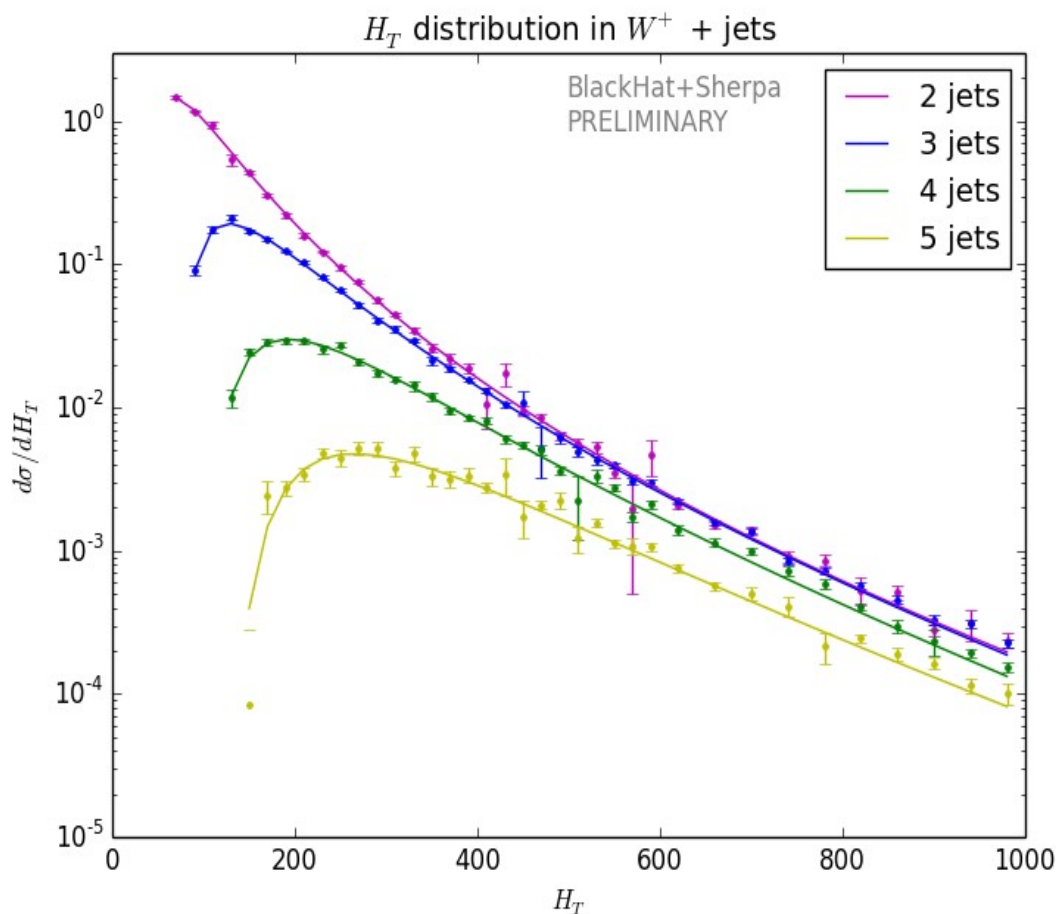
Extrapolation for ratios

- Ratio $V+n \text{ jets}/(V+n-1 \text{ jets})$
- Consistent with straight line for $n>2$
- Use extrapolation for 6 jets:
- W^- : $0.15 \pm 0.01 \text{ pb}$
- W^+ : $0.30 \pm 0.03 \text{ pb}$
- Consistent with extrapolation of charge asymmetry
- Error estimates through Monte Carlo method



Distributions

- What about distributions?
- Look at sum of transverse energies of the jets (HT)
- Cannot extrapolate the value of each bin separately
 - Statistical errors are too large
 - Different thresholds
 - Different peak positions



Distributions

- Instead find a parametrisation and extrapolate the parameters of the parametrisation
- Ansatz for the HT distribution:

$$\frac{d\sigma_{V+n}}{dH_T} = \left(\frac{N_C \alpha_s}{2\pi} \right)^n f(H_T) \mathcal{N}_n \ln^{\tau_n} \rho_{H,n} \left(1 - H_T / H_T^{\max} \right)^{\gamma_n}$$

$$\rho_{H,n} = H_T / (np_T^{\min})$$

HT Distribution

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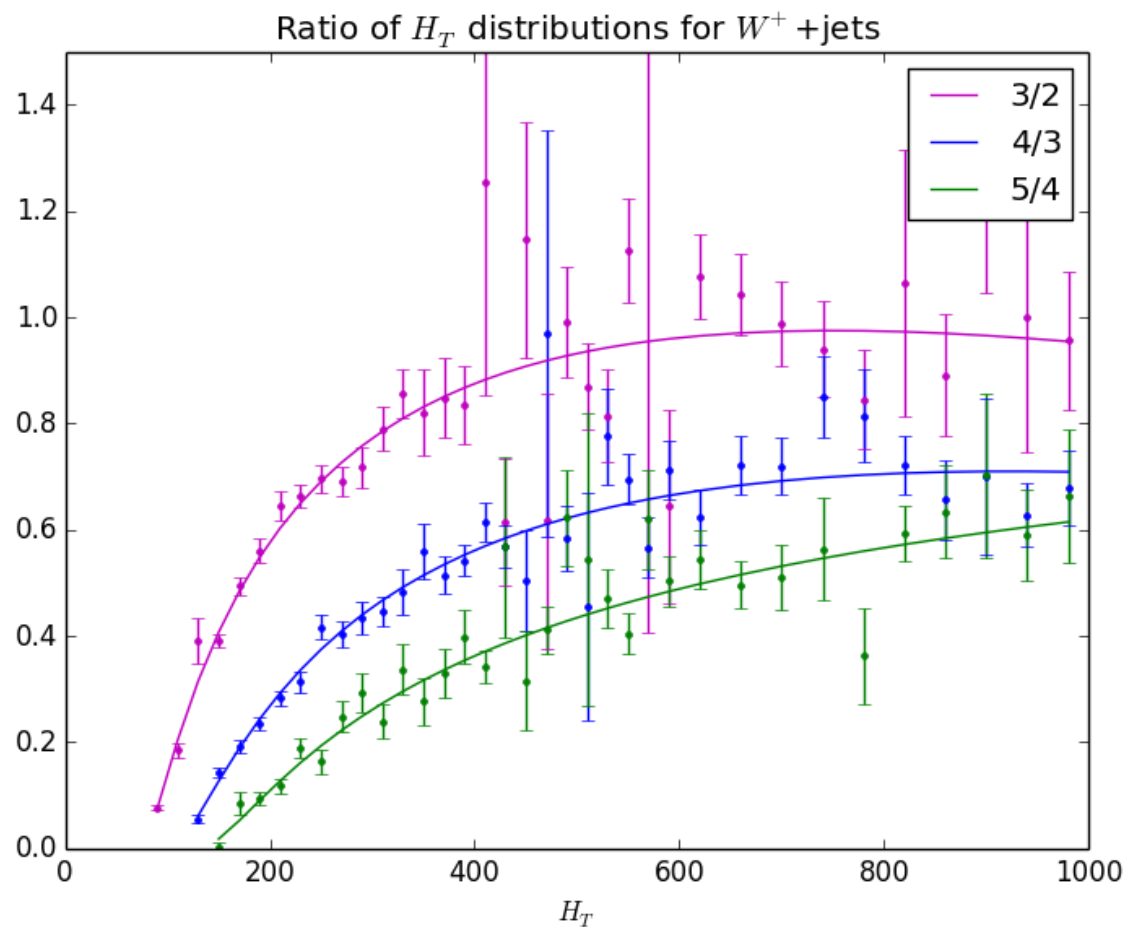
Independent of n

parameters

$$\rho_{H,n} = H_T / (np_T^{\min})$$

HT distribution

- Fit ratios to get the parameters



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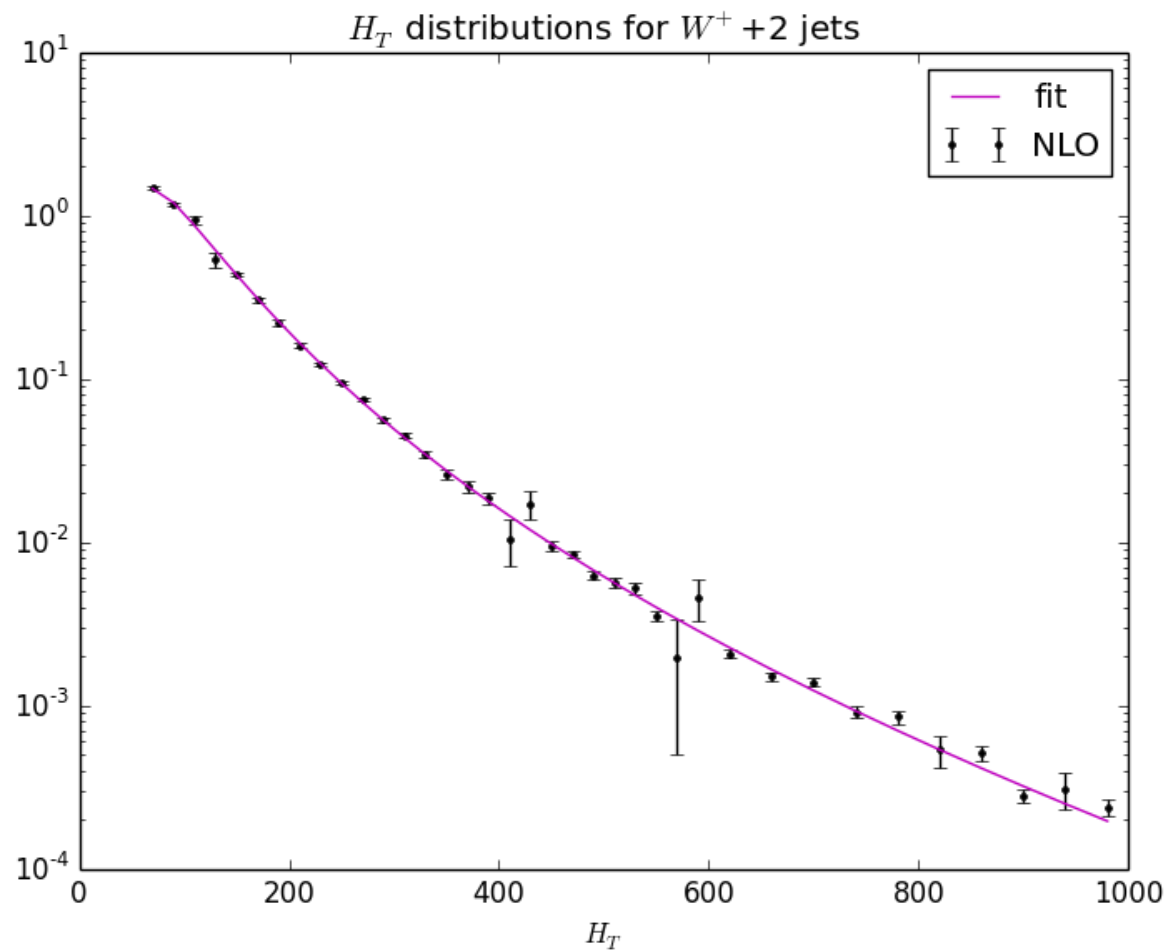
HT distribution

- With the parameters one can extract $f(H)$ from a distribution
- But it is more convenient to have an analytical form for it
- We can use the following form

$$f(H) = c \ln^r(H/10) \left(\frac{H}{2p_T^{\min}} \right)^{\omega_2} e^{-h_* H},$$

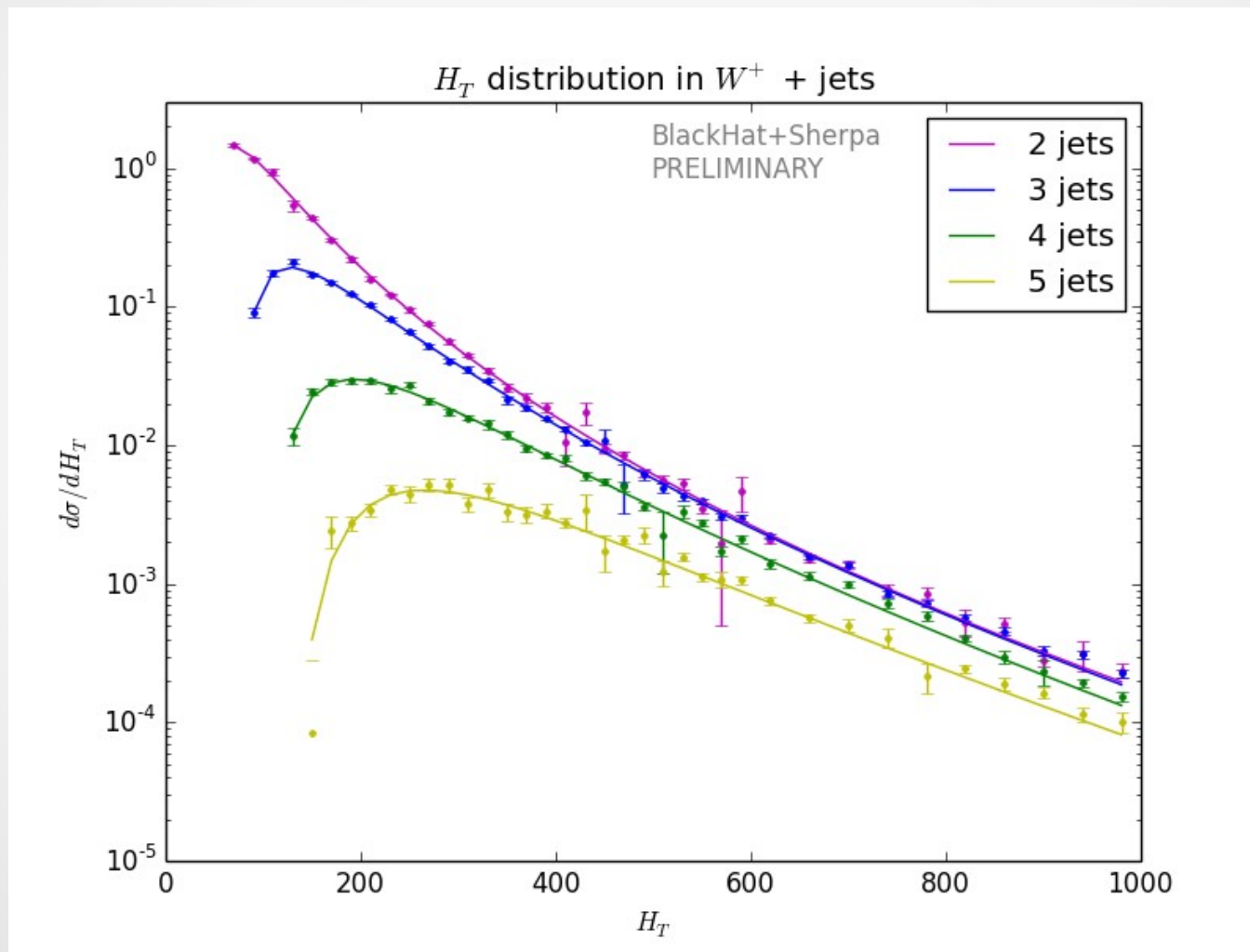
and extract the parameters from the W+2 jets distribution

HT distribution



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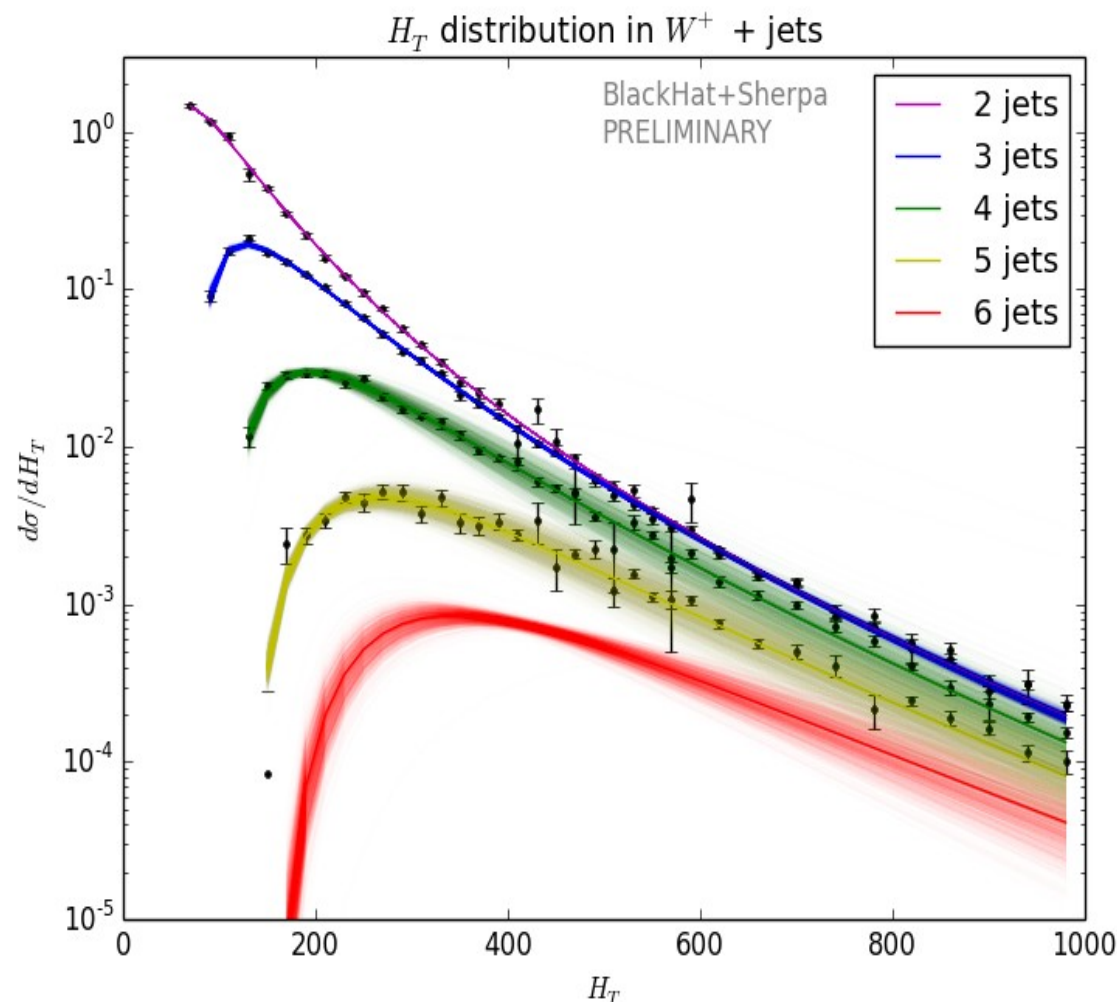
HT distribution



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Distributions

- Extrapolated HT distribution
- Uncertainty bands are estimated using a MC method



Outlook

- Calculate more classes of processes with BlackHat and Sherpa and provide n-Tuple files
- Explore new possibilities offered by Blackhat+Sherpa and the n-Tuple format
- Investigate pattern at high multiplicity
- Further physics studies
- Investigate combinations of several multiplicities